Efficiency Of Bacterial Disinfection

By A

Duct Mounted UV-AireÔ Air Purifier

By:

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Background

This product study evaluates the effectiveness of the UV-Aire air purifier in reducing the levels of bacteria with a single pass through a simulated air duct system. This device is designed to irradiate the air as it circulates through the home, so the single pass evaluation is the worst-case scenario use of this device. The air in the home will pass through the heating and air conditioning system many times a day, as the air is circulated throughout the home. Knowing the effectiveness of the UV-Aire in a single pass application, enables us to project how effectively the device will treat the air with multiple passes a day.

UV light technology has been successfully used for the disinfection of drinking water for years. Applications for air disinfection with the use of UV light technology include: commercial air treatment in hospitals, clean rooms, meat packing plants, bakeries, dairies, breweries, bottling plants and large commercial HVAC systems.

ORGANISM:

Serratia marcescens (ATCC 14756) was chosen as the test bacterium. The distinctive red colonies made it easy to evaluate from any background organisms. A raw test suspension of the organism of approximately 95,000 CFU/ml was used. As dispersed into the test system, this suspension yielded bacterial counts of 269 CFU/ft^3 @ 500 ft/min airflow and 107.5 CFU/ft^3 @ 1000 ft/min airflow. (CFU = Colony Forming Units)

TESTING STRUCTURE:

An 18" x 18" galvanized air duct, 38 feet long was constructed as the test chamber (see Figure 1). A fan was mounted at the exit end of the chamber and the treated air exhausted to the outdoors. To reduce contamination of the intake air, all air intakes on the exhaust side of the building were sealed. The exhaust fan was equipped with a flow adjustment to allow for adjustable air speeds measured in feet per minute (FPM) through the duct.

TESTING AIRFLOW RATE:

The airflow rate through the ductwork was adjusted to two nominal velocities of 500 ft/min and 1000 ft/min. The airflow velocities were measured at the center of the duct at the intake end of the test duct.

ORGANISM APPLICATOR:

An atomizing humidifier spray nozzle mounted at the center of the test duct intake was used to distribute the organism into the air stream. The application flow rate was 0.45 gallons per hour.

UV DEVICE:

A Field Controls UV-Aire air purifier model UV-18 was mounted onto the center of the side of the test duct 6 feet from the exit end of the chamber. The lamp is a UVC germicidal lamp (non ozone producing) 18 inches long with a UV output rating of 73 $\mu W/cm^2$ at 1 meter from the lamp.

AIR SAMPLING METHOD:

An Andersen N6 single stage "bioaerosal" sampler was used to take the air samples and distribute the sampled air onto agar medium. The test medium was Tryptic Soy Agar from PathCon, Inc. The air sampling pump airflow rate was 1 CFM.

The Anderson sampler method requires corrections to the actual colony counts on the plates. This provides a more accurate measure of the bacteria per cubic foot of the sample air. In the following tables, the *Serratia marcescens* Positive Hole Count values are the actual plate counts and the Corrected Particle Count values are corrected value based on Anderson correction tables.

Test Apparatus

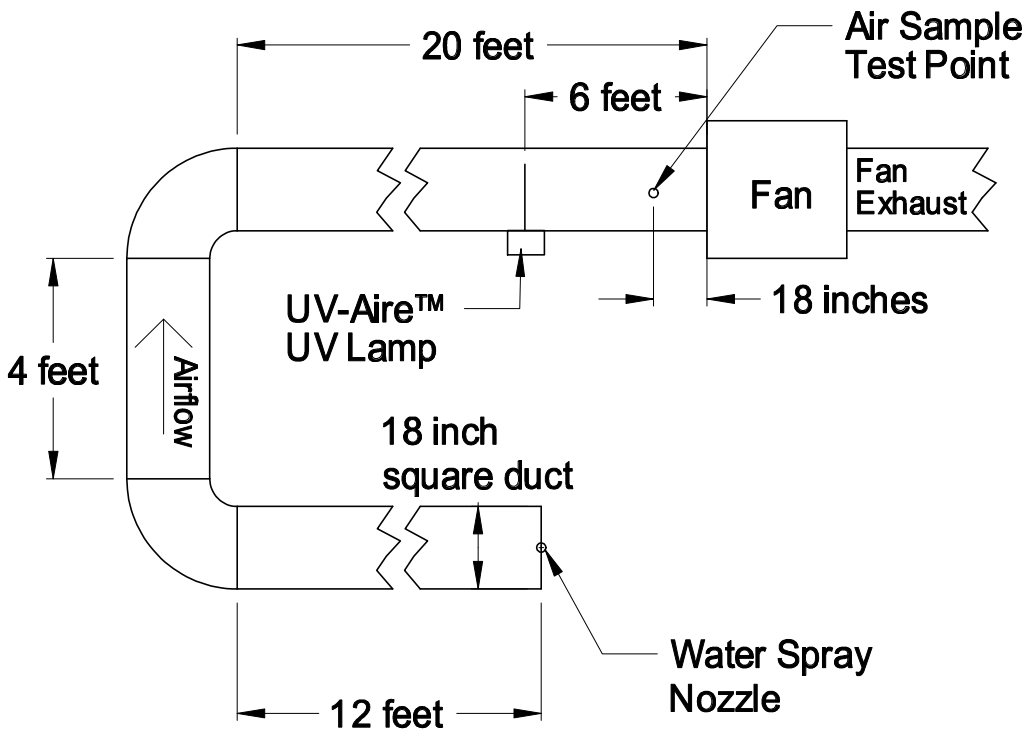

Figure 1

Testing Procedure

The testing was performed in two stages. The first stage operated the test chamber with the lamp off. (See table 1) This developed the control data or the base line bacterial levels for the comparison. The second stage operated the test chamber with the lamp on. (See table 2)

Two airflow rates were used to evaluate the lamp effectiveness based on exposure time. Airflow velocities through the ducts of a typical residential heating and cooling system range from 300 to 500 feet per min (fpm). For this study a base air velocity of 500 fpm was used. To decrease the exposure time, a second test was conducted with the airflow in the duct doubled to 1000 fpm. Since the effectiveness of UV lamps is based on the UV light output and exposure time, doubling the airflow reduces the effectiveness of the lamp.

The bacterium was cultured and the cells harvested to provide a suspension of known cell density. This was further diluted to provide gallon quantities of a test suspension containing an estimated 95,000 CFU/ml. This suspension was pumped through the spray nozzle mounted in the center of the duct inlet.

Five air samples were taken for each of the test velocities at short intervals (typically ½ to 2 minutes). This produced a large sample volume of air and reduced the levels of back ground bacteria and molds counts. The plate counts (colony forming units or CFU) for each of the five tests were totaled and divided by the total test volume of air. This produced the comparison value of (269 CFU/FT^3 of air) for the 500 FPM airflow and (107.5 CFU/FT^3 of air) for the 1000 FPM airflow. Due to apparent efficiency losses in the sampling method at the 1000 FPM velocity, the bacterium count yielded a 60% drop instead of the anticipated 50% reduction due to the velocity change.

Four air samples were taken at 1, 2.5, 3, 5, 6 & 10 minute intervals for each of the test velocities with the lamp on. The longer sample times with the lamp on were needed to obtain plate counts which would provide reliable estimates of the efficiency of disinfection, but with this, more background organisms were found. The plate counts were (18.00 CFU/FT^3 of air for the UV-18 and 2.56 CFU/FT^3 of air for the UV-18X) at 500 FPM airflow. They were 31.18 CFU/FT^3 of air for the UV-18 and 10.40 CFU/FT^3 of air for the UV-18X at 1000 FPM airflow.

Table 1: Control Data (*testing with lamp off*)

Sample Number	Air Sampling Duration (min)	Airflow Velocity fpm	*Serratia marcescens* Positive hole count	Corrected Particle Counts	CFU/FT^3 of air (count/min)
1	1	500	181	241	
2	1	500	193	263	
3	1	500	208	294	
4	0.5	500	117	138	
5	0.5	500	118	140	
Total min. = 4			**Total Corrected Particle counts** = 1076		269.00
1	2	1000	168	218	
2	2	1000	167	216	
3	2	1000	169	220	
4	1	1000	91	103	
5	1	1000	92	103	
Total min. = 8			**Total Corrected Particle counts** = 860		107.50

Table 2: UV-18 Test data and results (*testing with lamp on*)

Sample Number	Air Sampling Duration (min)	Airflow Velocity (fpm)	*Serratia marcescens* Positive hole count	Corrected Particle Counts	CFU/FT^3 of air (count/min)	%Survival CFU/Control	Log Reduction	% Effective
1	1	1000	30	31				
2	1	1000	32	33				
3	3	1000	88	99				
4	6	1000	145	180				
Total min = 11			**Total Corrected Particle Counts** = 343		31.18	29.01	0.54	70.99
				Control:	107.50			
1	1	500	13	13				
2	1	500	19	19				
3	3	500	57	61				
4	6	500	92	105				
Total min = 11			**Total Corrected Particle Counts** = 198		18.00	6.69	1.17	93.31
				Control:	269.00			

Table 3: UV-18X Test data and results (*testing with lamp on*)

Sample Number	Air Sampling Duration (min)	Airflow Velocity (fpm)	*Serratia marcescens* Positive hole count	Corrected Particle Counts	CFU/FT^3 of air (count/min)	%Survival CFU/Control	Log Reduction	% Effective
1	2.5	1000	21	22				
2	2.5	1000	27	28				
3	2.5	1000	28	29				
4	5	1000	48	51				
Total min = 12.5			**Total Corrected Particle Counts**	= 130	10.40	9.67	1.01	90.33
				Control:	107.50			
1	5	500	8	8				
2	5	500	10	10				
3	5	500	17	17				
4	10	500	28	29				
Total min = 25			**Total Corrected Particle Counts**	= 64	2.56	0.95	2.02	99.05
				Control:	269.00			

Conclusion

UV-Aire Model	Airflow velocity (fpm)	Percent Reduction of Bacteria	Percent Survival of Bacteria	Log Reductions of Bacteria
UV-18	500	93.31	6.69	1.17
UV-18	1000	71.99	29.01	0.54
UV-18X	500	99.00	0.95	2.02
UV-18X	1000	90.33	9.67	1.01

The testing showed the UV-Aire lamp yields at least a 90% reduction of the test bacteria with a single airflow pass through a duct system at typical airflow rates. This efficiency will not be the same for all bacteria and molds since each organism requires different exposure times at the same UV output energy level.

At the higher velocity, the lamp still reduced the bacterial levels by at least 71 % at a 50% decrease in the exposure time. Since the reduction efficiency is based on lamp UV output and exposure time, the assumption can be made that decreasing the exposure time to the UV light is similar to testing an organism that requires a higher UV energy requirement to kill the bacteria. The log reductions in bacterial levels were very close to theoretical values. Within the limits of testing accuracy, twice as many log reductions (0.54 vs. 1.17 and 1.01 vs. 2.02) occurred with twice the exposure time.

This testing and the results clearly show that the exposure of the air to the UV light of the UV-Aire will reduce levels of airborne bacteria.